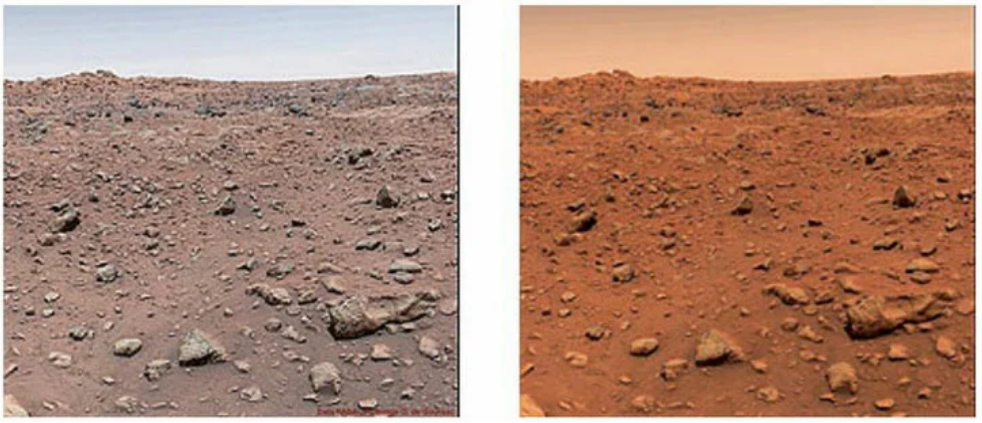
54. How does a "Martian" camera work? Where is the "color target" on the rover for color calibration?

14-18 minutes

For more than forty years now, it has not been possible to get an answer to a seemingly simple question - what color is the sky and what is the actual color of Mars?

How it started .

> The very first color photograph in the history of mankind, taken on the surface of Mars, was obtained in the summer of 1976 from the Viking Lander 1 lander. And already on it, people saw the blue sky and the colors of the landscape, similar to those on Earth (photo on the left). But just a few hours later, NASA released an "updated" version of the same image (photo on the right), which amazed the world with its orange skies and red soil.



> Two versions of NASA's first color image from the surface of Mars (Viking Lander 1)

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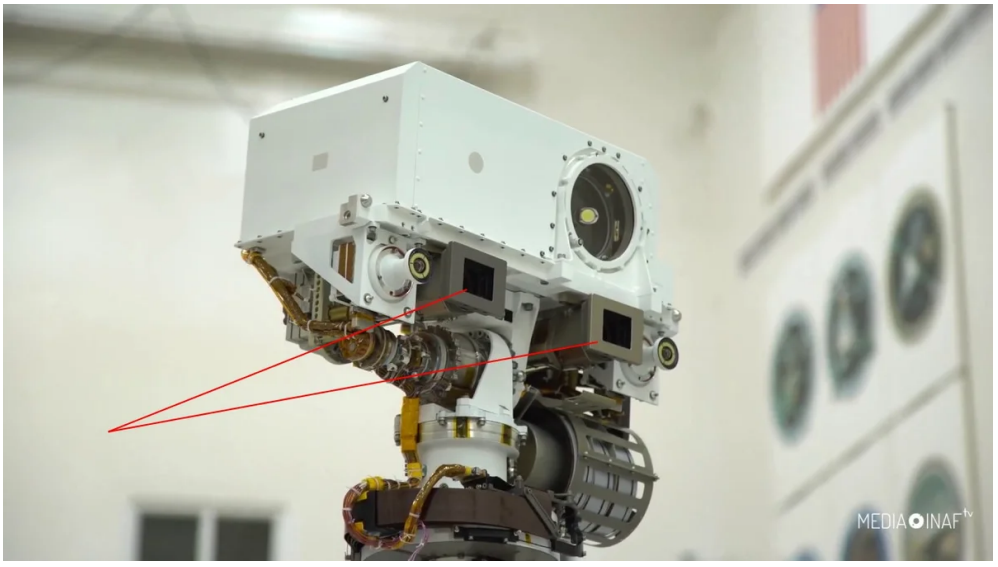
Believe it or not - the NASA website currently contains about 800 thousand (!) Images from Mars taken by different rovers: Opportunity, Curiosity, Spirit and, of course, Perseverance. But, they say that from these images it is impossible to determine the real color of Mars, because all the images are actually black and white, and the color ones are taken in false colors. Let's try to figure out if this is really so.

There are many different cameras on the Perseverance rover (for different purposes). On the mast of the rover, along the edges there are navigation cameras, they are round, but closer to the center, with a rectangular mess, there are two Mastcam-Z cameras, left (L) and right (R). It is these cameras that take most of the photos that are then distributed on the Internet.



Two Mastcam-Z cameras on the mast of the rover.

Two Mastcam-Z cameras on the mast of the rover.

They are located high on the mast.

The size of the rover compared to the height of a person. Cameras are located at the top of the mast.

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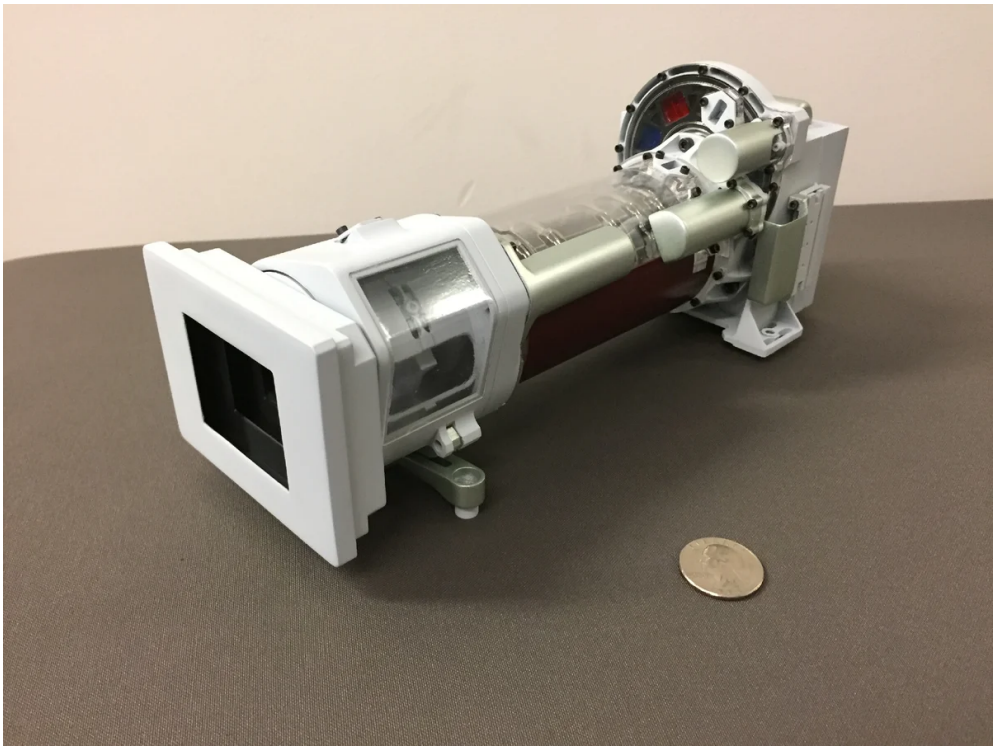
Despite the original design and unusual appearance, this is the most ordinary camera, exactly the same one that many inhabitants of the Earth have.

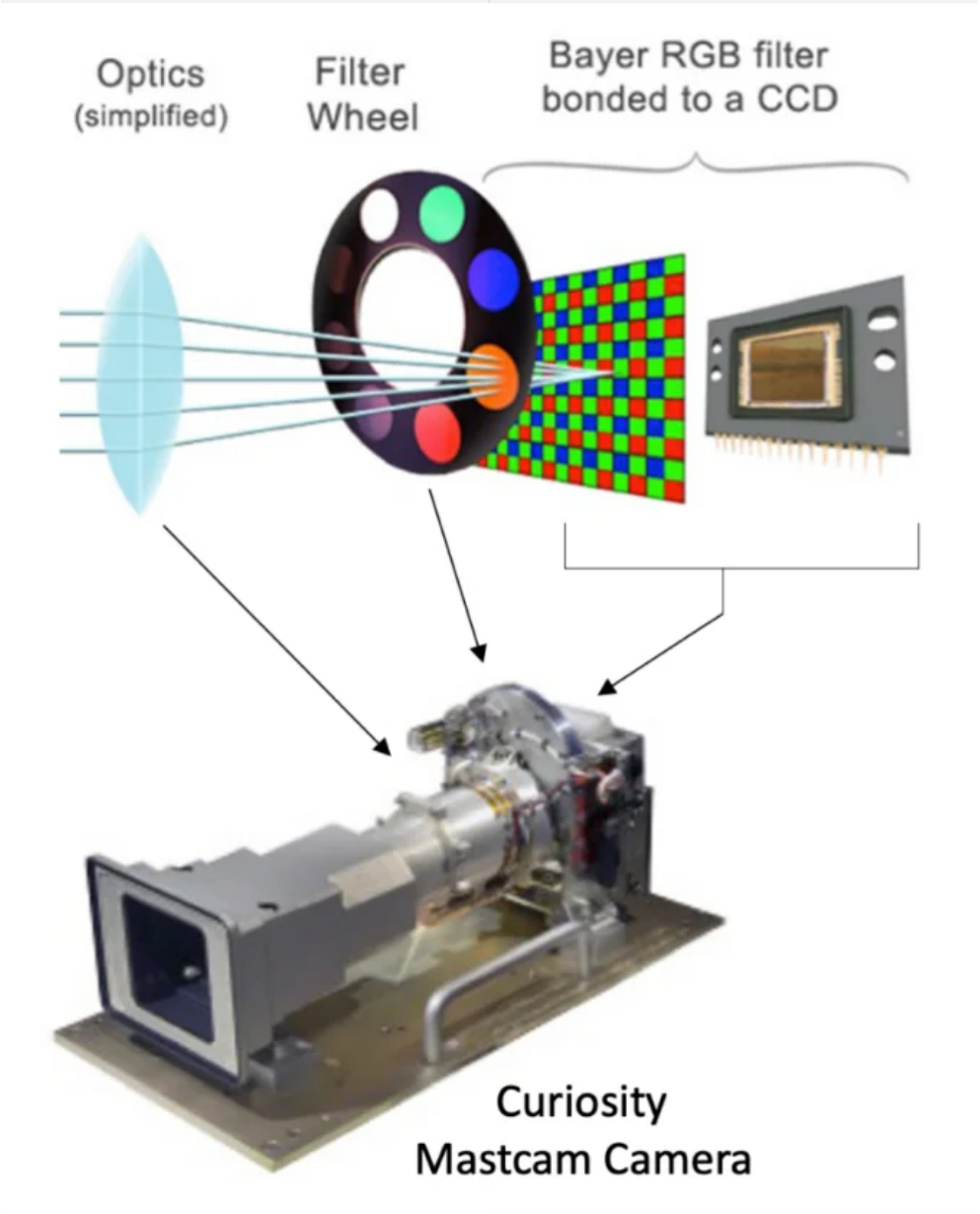


Mastcam-Z "Perseverance" camera. The disc with color filters is clearly visible.

Mastcam-Z "Perseverance" camera. The disc with color filters is clearly visible.

It has exactly the same light sensor and Bayer filter as in a conventional digital camera. And about the same variable focal length lens that we call "zoom".

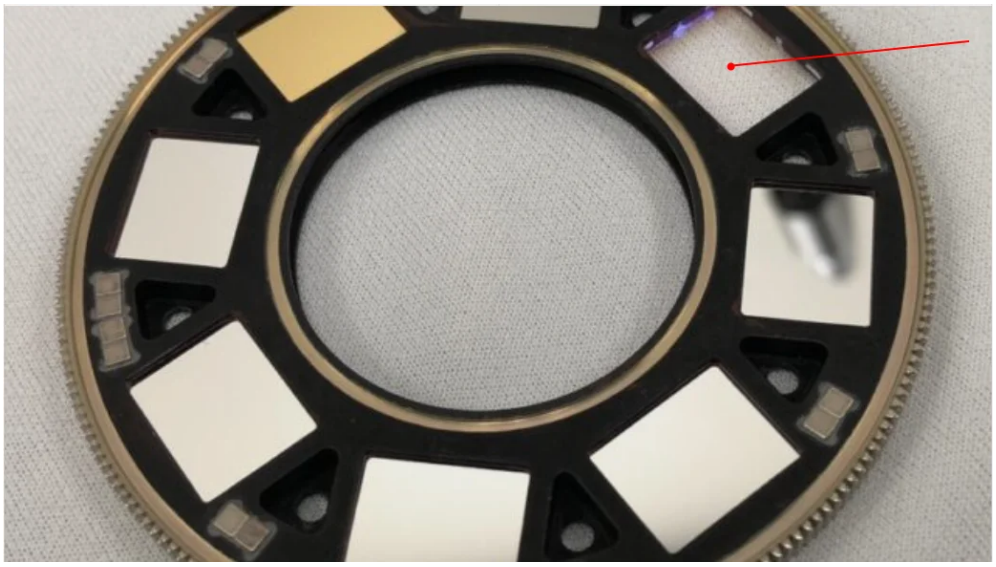
The only difference is that there is a wheel with additional filters behind the lens. But this is also not a fundamental difference, since many photographers buy additional filters and also shoot through them.



Mastcam camera of the Curiosity rover. The "Perseverance" camera is exactly the same, it differs only in a set of filters.

Mastcam camera of the Curiosity rover. The "Perseverance" camera is exactly the same, it differs only in a set of filters.

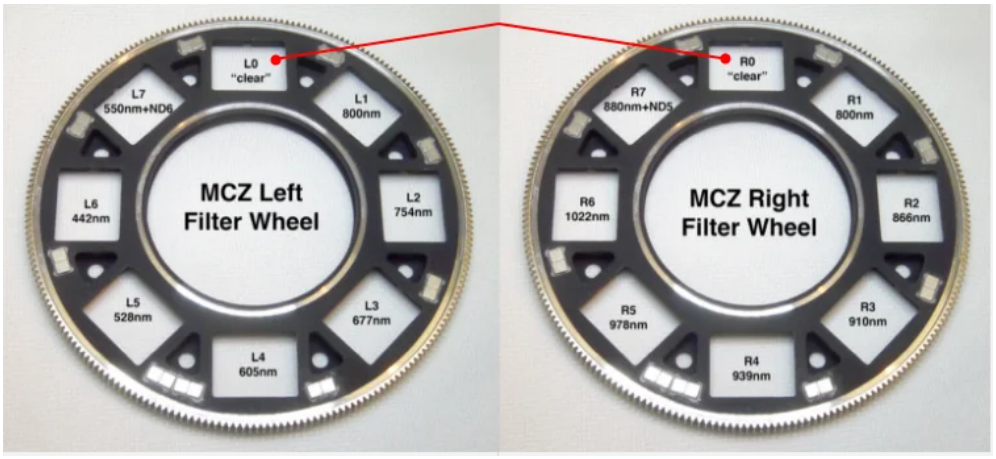
This disc with filters has one empty window (in the figure, a red arrow points to it). And when this window is installed behind the lens, there is no additional filter when shooting, and the camera "sees" just like any digital camera. A digital camera "sees" in much the same way as the eye: blue sky - blue, green grass - green, orange sand - orange.



Disc with light filters.

Disc with light filters.

Since the rover has two cameras (left and right), there are also two disks with light filters. And in each disc there is a clear glass ("clear") - left zero (LO) and right zero (RO).



Both the left disc and the right one have a window with transparent glass.

Both the left disc and the right one have a window with transparent glass.

And it turns out that the rover takes most of the images without additional filters, through these transparent windows.

This is what is written on the website of the camera manufacturer .

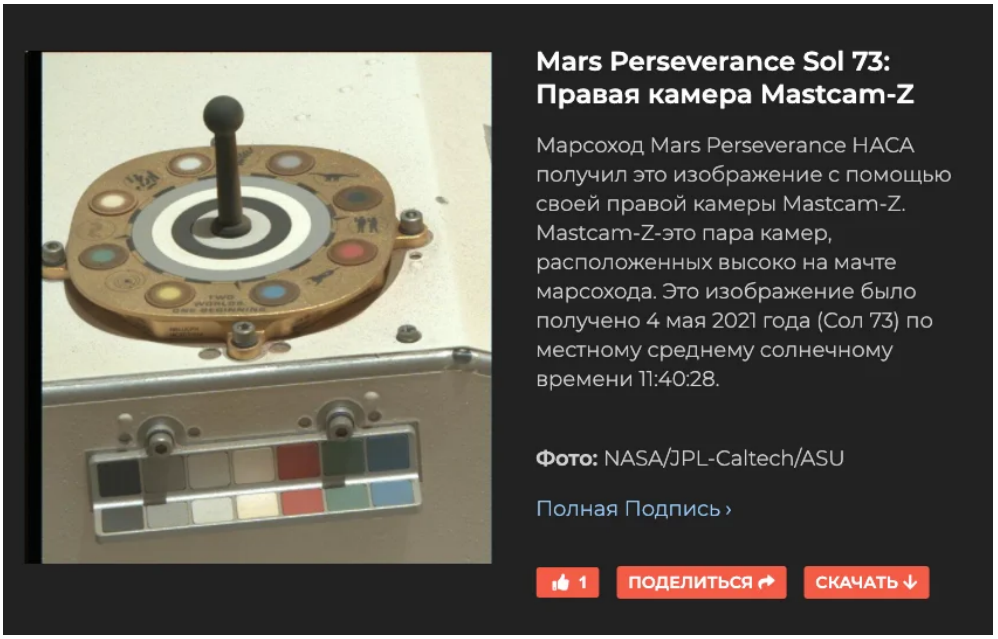
> Take a good look at the two images above. The top one is a simple RGB image from the R0, or right-eye clear filter. This is a close approximation to how your own eye sees color, and it’s the kind of color imaging that Mastcam-Z will do most of the time on Mars.

Translation (automated):

> Take a close look at the two images above. The top one is a simple RGB image using R0, or a clear right-eye filter. This is a close approximation to how your own eye sees color, and this is the kind of color image that Mastcam-Z will do most of the time on Mars.

In other words, most of the "Martian" images were taken with a "standard" digital camera.

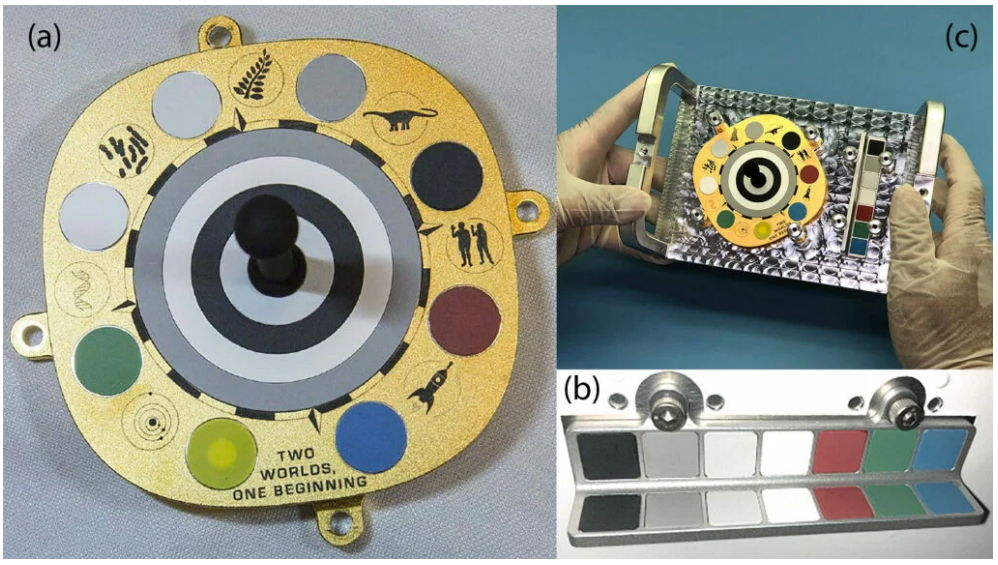
For an objective assessment of the color rendition, gray and color scales are used, the so-called calibration targets, there are two of them on the rover.



> Calibration scales on the rover.

Calibration scales on the rover.

What these scales should be, ideally, is shown in the following figure. Photo on the left, under the letter "a", normalized in a photo editor at the Niels Bohr Institute (Denmark, Copenhagen), figures "b" and "c" - at NASA / JPL-Caltech / ASU.



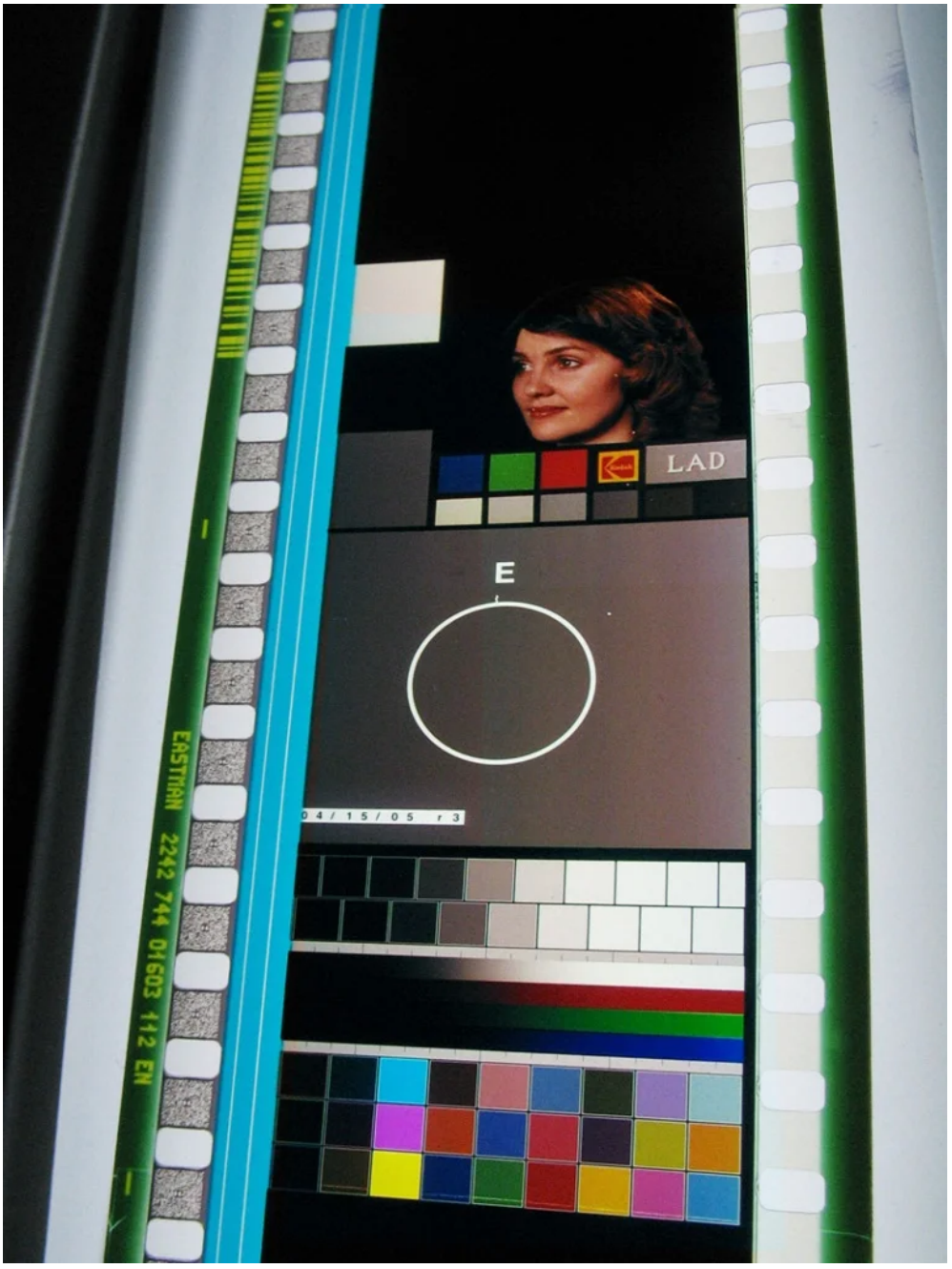
"Inspection" photograph of the calibration targets.

"Inspection" photograph of the calibration targets.

Measurements in Photoshop show that the outer round gray rim on the primary target in figure "a" is excessively blue, and the really neutral gray is the small circle near the head of the dinosaur. But in the figure "c" all the gray fields are drawn in a gray-yellow tone.

Gray fields are used for reproduction, because even a slight excess color tone is immediately detected on them.

I once worked as a color installer in a film copier. So, in all film prints, in addition to the control gray fields, there are also color scales and even a "girl" - for assessing complexion. When films are being printed for cinemas, a full-length film (which is about 3 kilometers of film) is divided into parts of 600 meters (one part, 600 meters, takes about 19-20 minutes). And so that all parts of the film have the same color tone, a special scale with a large gray field is imprinted at the beginning of each part. These frames with gray and color scales are located on the leader line after the filling end, about 4 seconds before the start of the image, so the audience simply does not see the "reference girl" and the scale during viewing. There is a density circle in the large gray field.



Control scales in each part of the film and a circle for measuring the density. The blue track on the left is analog stereo audio. Small squares between perforations, such as a QR code, are Dolby Digital sound (5 + 1).

Control scales in each part of the film and a circle for measuring the density. The blue track on the left is analog stereo audio. Small squares between perforations, such as a QR code, are Dolby Digital sound (5 + 1).

The technical control department makes sure that the density values in all film copies are strictly the same and correspond to the original brought from abroad (if a foreign film is printed for film distribution). Kodak calls this control method LAD (Laboratory Aim Density). These

three letters, LAD, you see to the right of the girl's face. For those who have worked on a densitometer, I can name the density value that must be maintained on a gray field - this is
about 1.10. If a color rendition occurs in a film print, then first they look at what the density of the reference gray field is, and whether any chromaticity has appeared in this field. If the "girl" and the large gray field are printed correctly, then the whole further film will be the same color as the authors intended. This control technique has been around for half a century and has proven itself well.

In the Soviet Union, film prints used a gray polka dot scale developed at NIKFI (Research Film and Photo Institute) - on a light gray background there were round (pea-shaped) fields: white, black and gray. In the USSR, when there were still no personal computers and video tape recorders were a rarity, film copies on 8-mm film were produced for film lovers. To control the color rendering during mass printing, a gray polka dot scale was pasted into the negative, which in the positive should be neutral gray. For example, here is a copy of the cartoon "Just you wait!", Released more than 30 years ago, in the late 1980s.

A copy of the cartoon "Well, wait!" on 8mm film.

A copy of the cartoon "Well, wait!" on 8mm film.

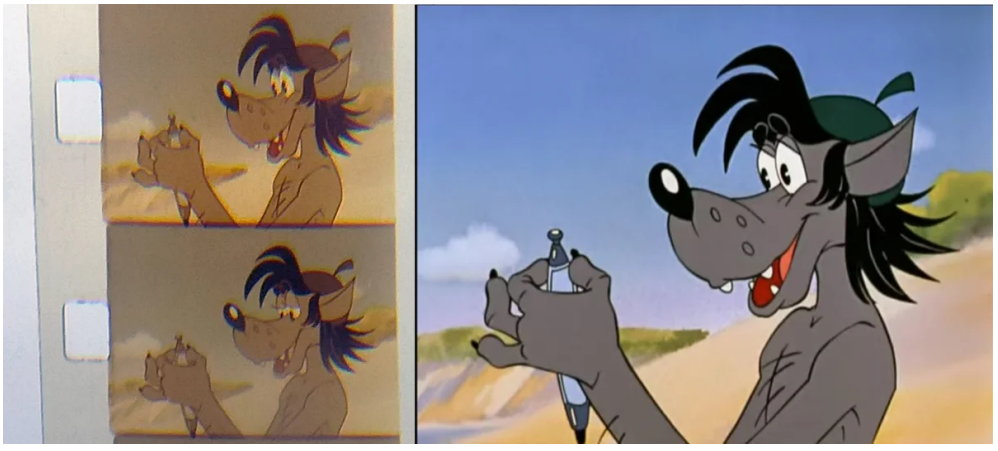
After the identification part, which indicates the name of the film, the speed of the display (18 fps), the type of film (8-super), etc., there was a polka-dot scale. It can be seen that instead of gray fields, there are

brown-brown circles on the film - the film has faded, the blue dye has collapsed.

Identification part of the film and gray polka dot scale.

Identification part of the film and gray polka dot scale.

From this type of control gray scale, you can immediately determine that in the film print there will be a shift in color to a brown tone, there will be practically no blue color, and the green color, consisting of cyan and yellow dyes, will look dirty yellow.



On the left is a positive image on a faded 8mm film print, on the right is an image digitized from the negative and corrected for the gray field.

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For printing from DIGITAL media onto film, Kodak uses a different "reference girl", but also with a gray scale. Three numbers "445" can

be seen in the gray field.

Reference image for printing from digital media. On the left - negative on the Intermedia film strip, on the right - digital positive.

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In a positive with a color depth of 10 bits (where the number of gradations is 2 to the 10th power = 1024), the gray field should be located approximately in the middle of this area and have a brightness of "445" (three identical values for R, G, B). In an 8-bit image, the mid-gray field can have luminance values from 105 to 118. When contrast is changed (in the image), the white fields can be whitened, the darkest fields can merge with black, and only the mid-gray always remains the same brightness (lightness). The control of the color correction accuracy is carried out only on the medium-gray field. In this case, not only the absence of chromaticity in the gray field is controlled, but also the degree of lightness of this gray field is recorded.

In the photographs sent from Perseverance, the calibration scale has a clear excessive tint. We enlarged the image in Photoshop and carefully examined the scale. The large gray border on the primary radiometric calibration target (circular scale) has a predominantly yellow-green color, which indicates incorrect color correction.

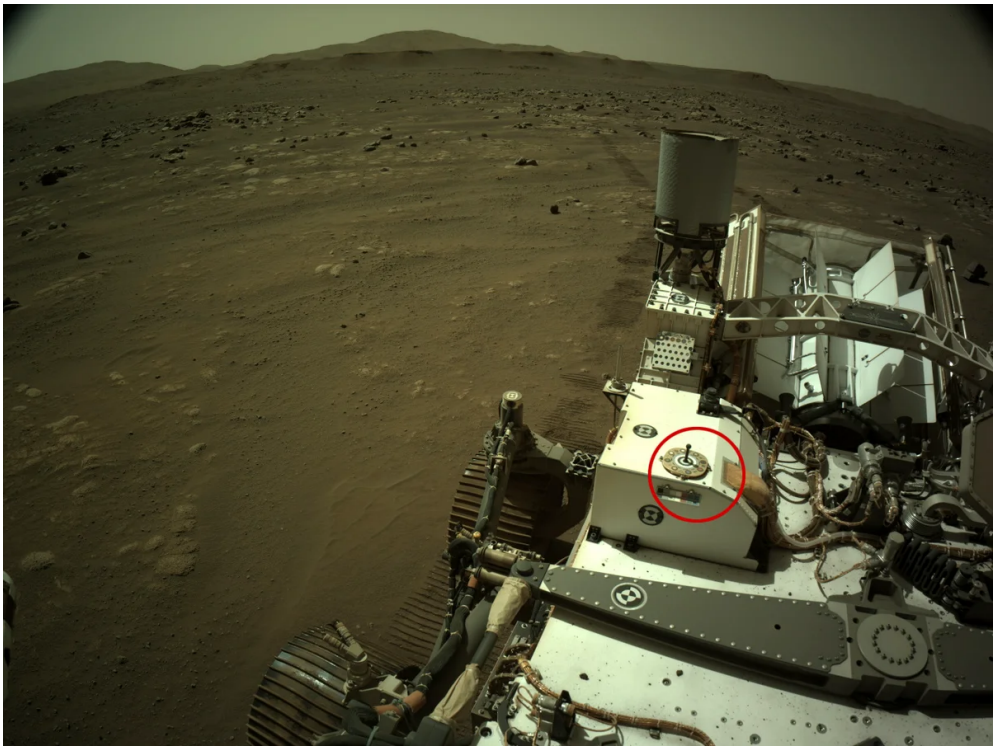


Photo taken by Perseverance in early May 2021. The rover's calibration bars are circled in red.

Photo taken by Perseverance in early May 2021. The rover's calibration bars are circled in red.

In this photo in Photoshop I measured the RGB values of the gray field on the primary (round) and on the secondary (rectangular) scale with an eyedropper and tried to bring these values to those obtained when measuring the "inspection" reference scales. I did not use "Automatic color correction", but a manual change of "Color balance" in RGB. After these corrections, the "Martian" landscape became very similar to the terrestrial one.

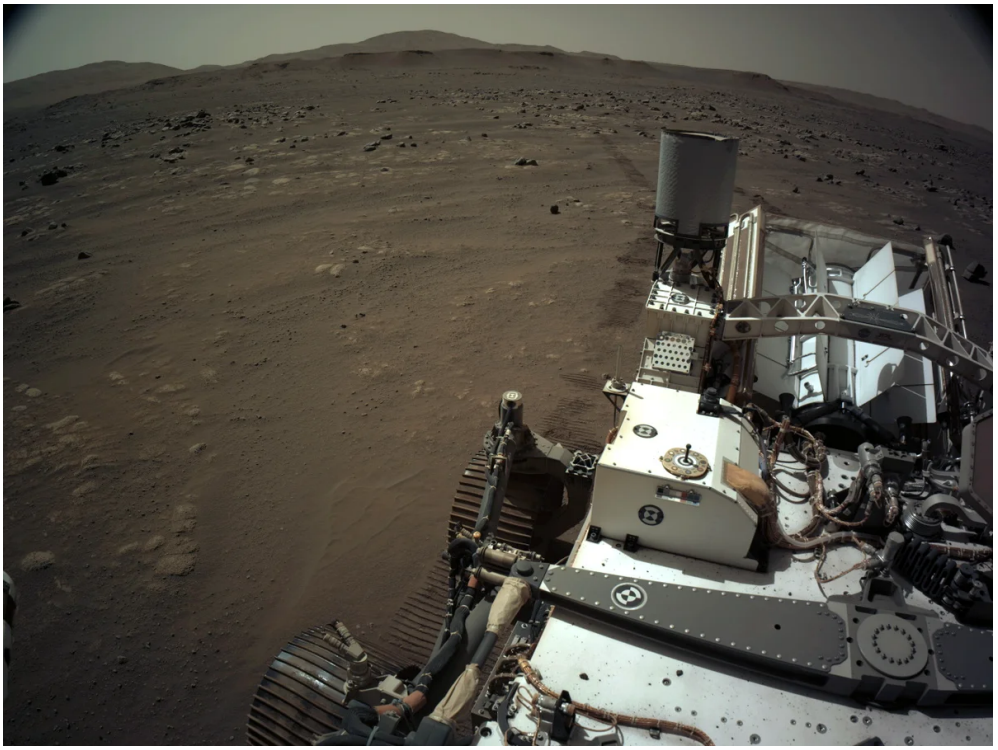
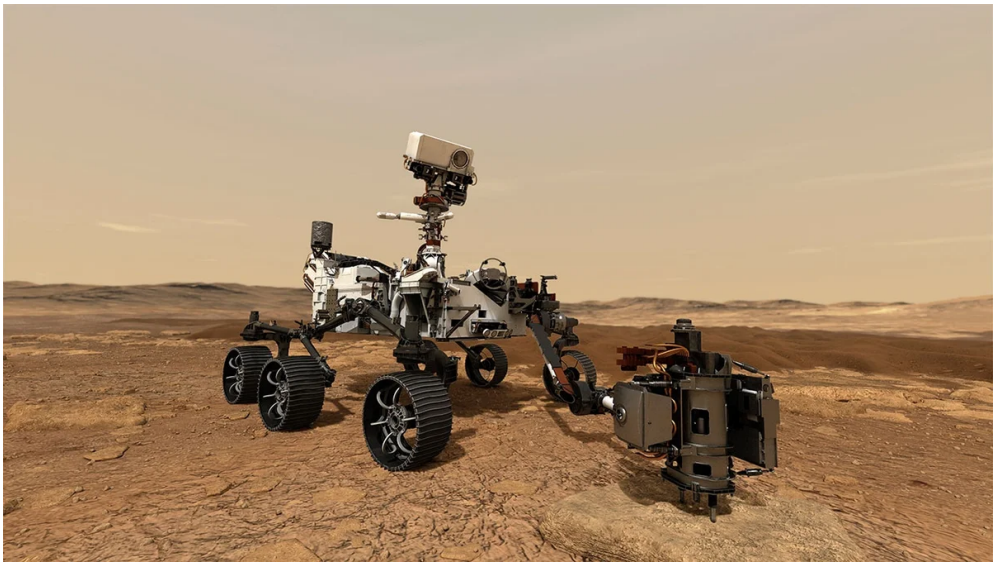


Photo after color correction on the calibration target.

Photo after color correction on the calibration target.

In the frame, we see strong vignetting (darkening of the corners) due to the wide angle of coverage of the lens. In the upper left corner, you can even see the edge of the lens barrel or sun shield. This vignetting darkens the sky a lot.

When the rover is shown in cartoons, it is often the sky that takes up half of the frame.



The rover in a cartoon demo.

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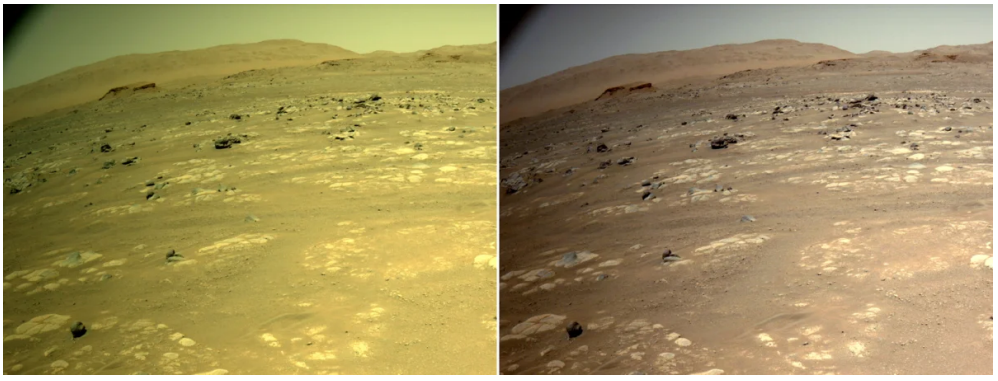
And when they show, as it were, real pictures from Mars, they try to show the sky as little as possible, in the form of a narrow strip on the horizon.

In almost all color images, we see an excessive yellow-green tone. Even the stones in the shadows are green. After color correction, the unnatural green color disappears, and we see our usual "earthly" blue sky at the horizon.



On the left - a snapshot of the "Martian surface" taken by "Perseverance" on May 9, on the right - the same frame after color correction.

On the left - a snapshot of the "Martian surface" taken by "Perseverance" on May 9, on the right - the same frame after color correction.

If you look at the rover in terrestrial conditions, you will notice that the white surfaces of the rover differ little from the white coats of NASA workers.

The white robes and white surfaces of the rover are very similar.

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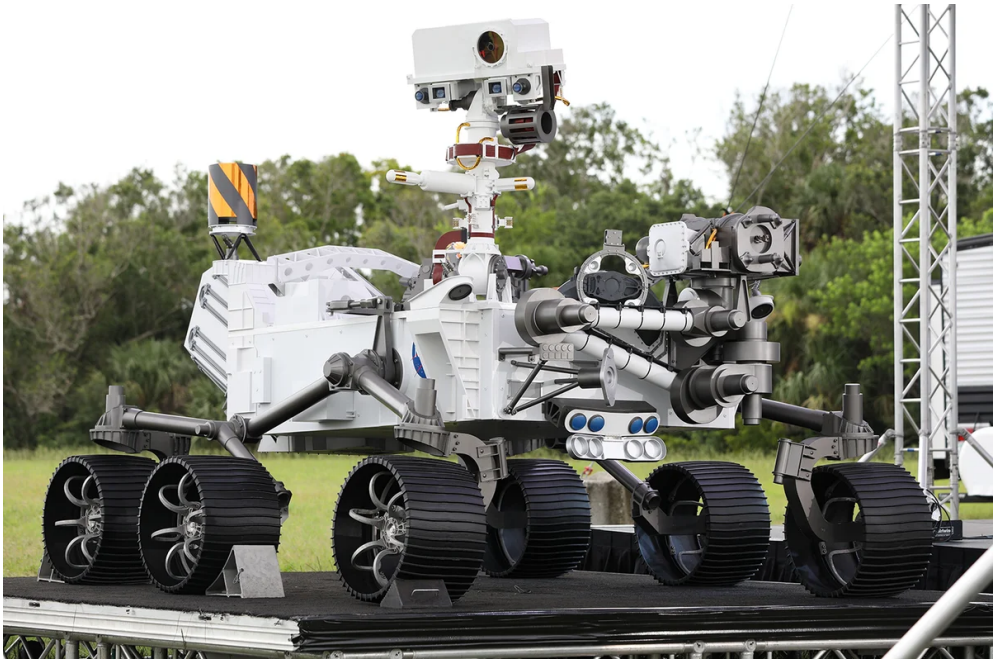
And gray surfaces are almost perfectly gray, without any shade.



Model of the Perseverance rover.

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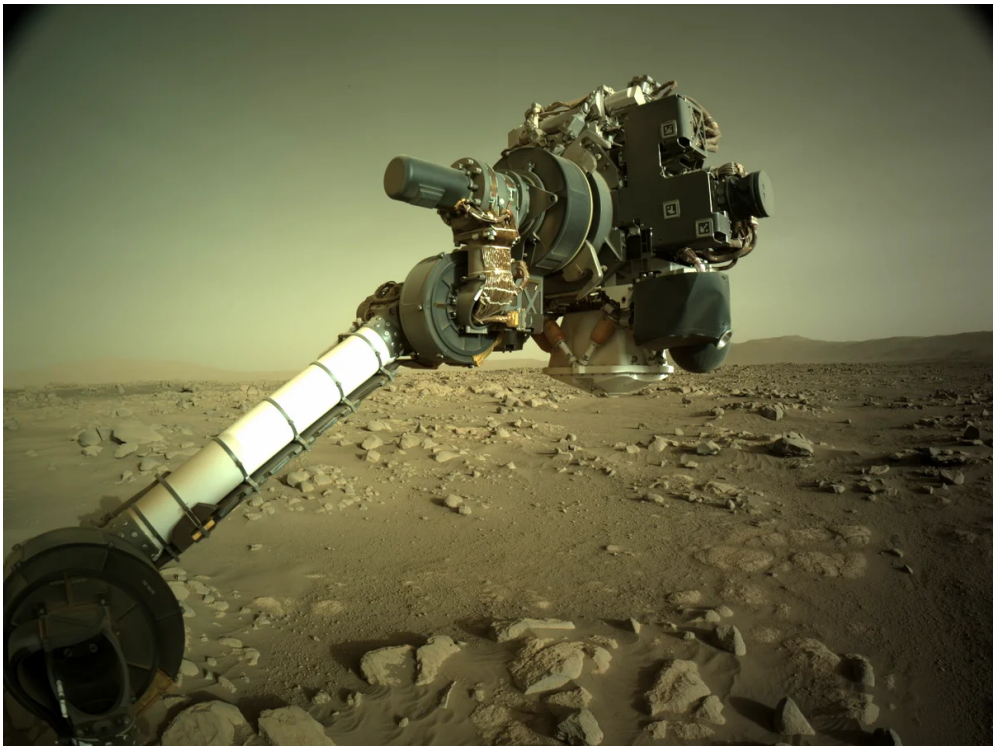
Manipulator arm with ultraviolet spectrometer. Details in neutral gray.

Manipulator arm with ultraviolet spectrometer. Details in neutral gray.

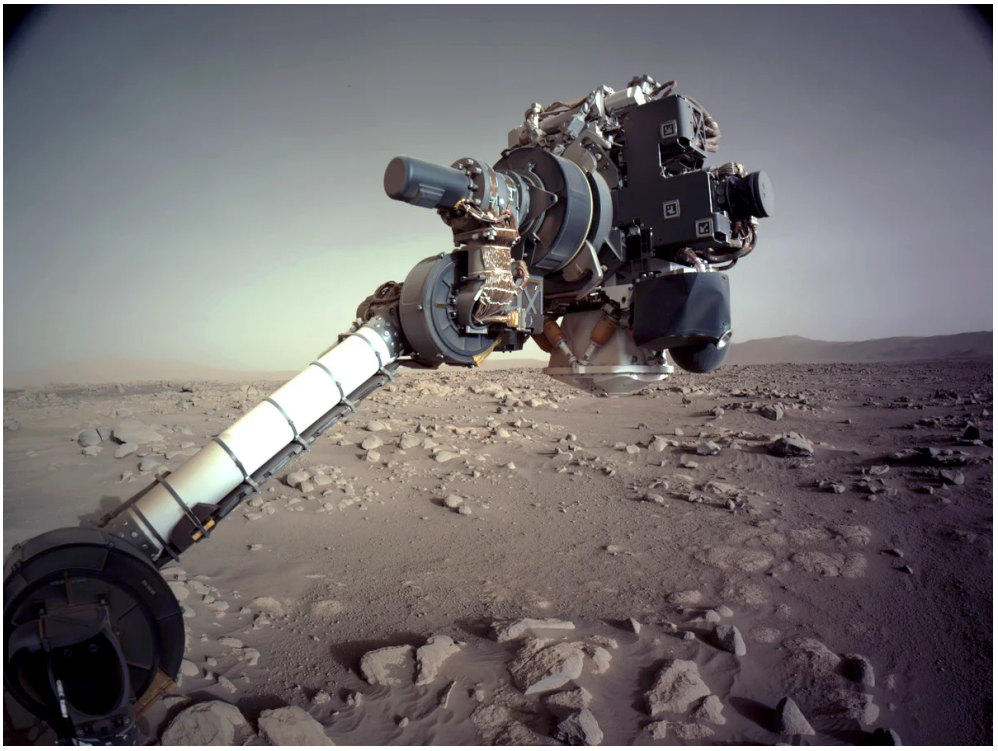
And in the "Martian" images, the body of the ultraviolet spectrometer on the manipulator arm looks not gray, but dark green. There is also an X-ray spectrometer at the bottom. Its body should also be neutral gray. But instead, we see a deliberate distortion of color with a departure in a yellow-green tone.



A manipulator arm with spectrometers, filmed by Perseverance.

A manipulator arm with spectrometers, filmed by Perseverance.

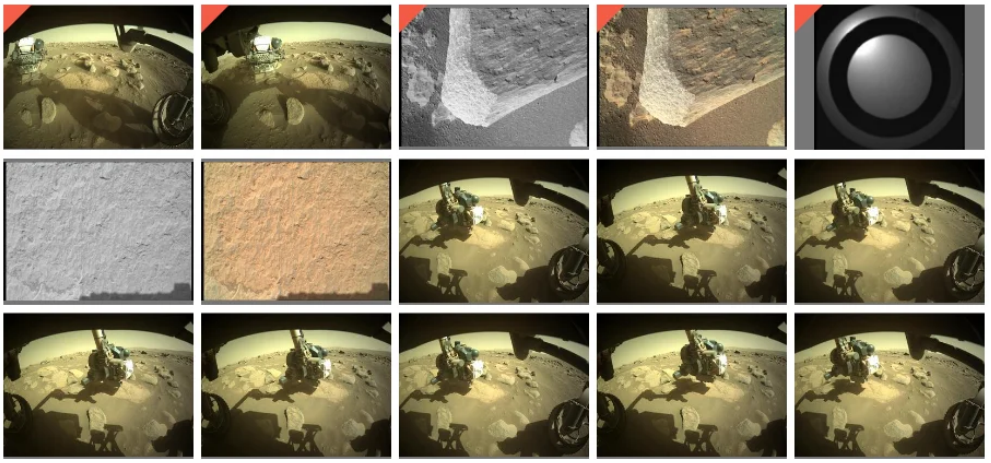
After color correction for gray details, we find a completely terrestrial landscape in the "Martian" image.



The same frame after after correction for gray details.

The same frame after after correction for gray details.

So what are we seeing? **Most of the color images taken by the rover are deliberately tinted yellow-green.**



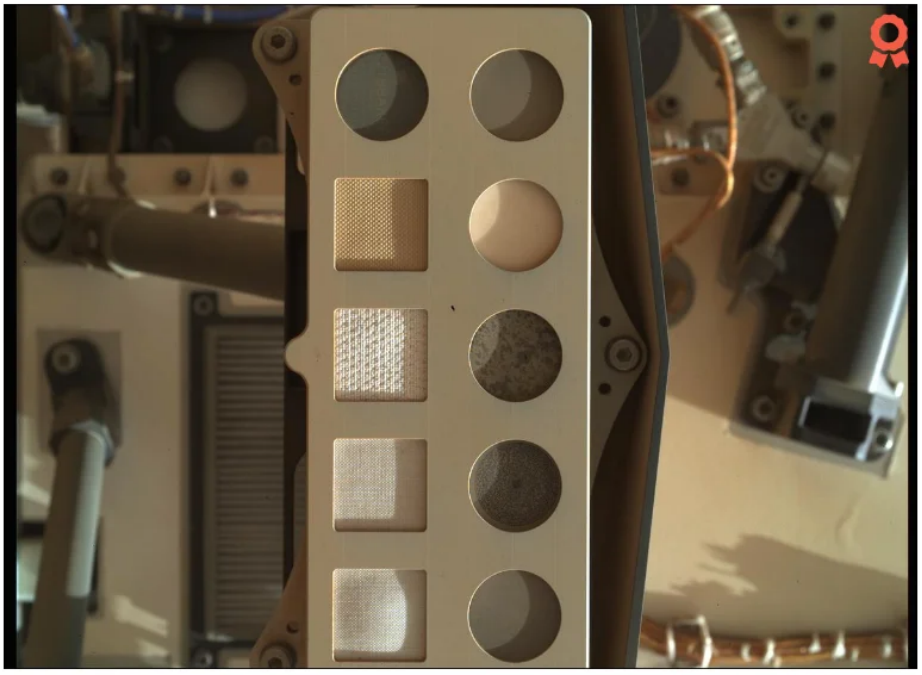
A sequential series of photographs from "Perseverance". In many frames there is an excess of yellow-green color.

A sequential series of photographs from "Perseverance". In many frames there is an excess of yellow-green color.

And this is despite the fact that there is a color target with gray fields in the frame, according to which you can fine-tune the color rendition. Apparently, this artificial color distortion is done in order to camouflage the obvious fact that Martian landscapes are filmed on Earth.

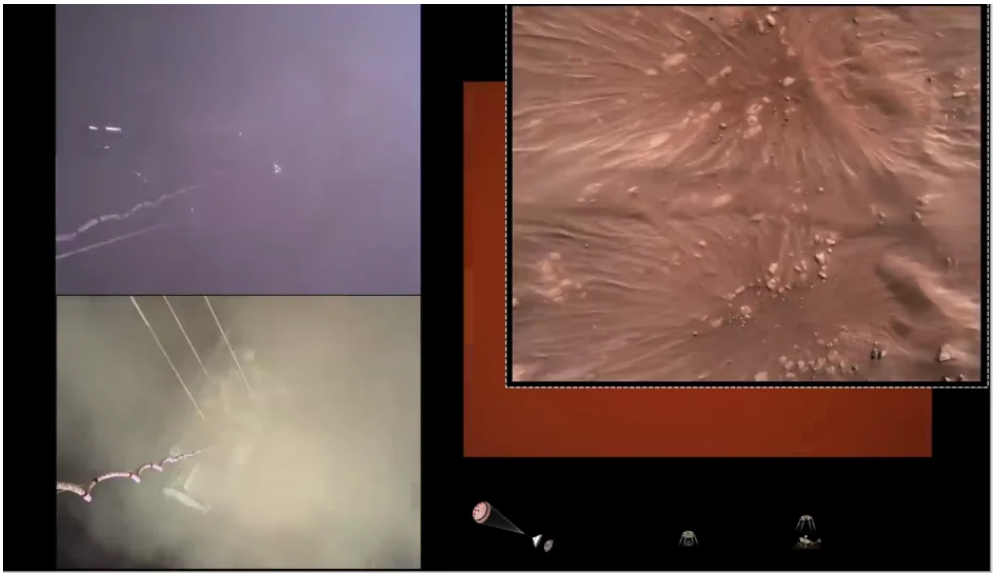
Of course, they will now write to me in the comments that the sky of Mars, due to constant sandstorms, should itself be orange or yellow. And I will post a photo in response - how much the rover was covered with sand for 5 weeks on the Red Planet.

Mars Perseverance Sol 26: WATSON Camera



Эта фотография была выбрана общественным голосованием и представлена в качестве "Изображения недели" для **5 - й недели (14 марта-20 марта 2021 года)** миссии марсохода Perseverance на Марсе.

Something not visible a speck of dust! Where is the effect of sandstorms? But besides, judging by the footage of the "live broadcast" of the landing, the entire rover should simply be covered with sand! And this is not smoke from the nozzles of the "sky crane" engines, but it is the sand that fills the rover, because, as NASA lawyers explained to us, the jets of burning gases are completely invisible.



The rover, when landing, is buried in clouds of sand.

The rover, when landing, is buried in clouds of sand.

Since the topic of sand and sandstorms on Mars is very interesting, then, probably, you will have to write an article on this topic, having found on the Internet the most interesting on this issue.

I also foresee questions about photographs from Mars in false colors. Of course, such photographs exist. I am already writing an article about this.

*

Cameraman L. Konovalov was with you. Until next time!

You know, earlier, when I did not delve into the question of how the Martian images were taken, I thought that the Americans were doing well with Mars, not like the Moon. But the more I look at the materials "on Mars", the more I am indignant at the unceremonious deception.

Shooting under the light of a narrow-band low pressure sodium lamp.

Shooting under the light of a narrow-band low pressure sodium lamp.

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